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# Notes on Instrumentation for EMI Testing to FCC, VDE and Other Mandates

## 1.0 Definitions

To begin this discussion of basic instrumentation needed for EMI testing, it is appropriate to review some definitions.

EMI is electromagnetic interference and is the emanation from a device of RF energy which has the potential of interfering with the proper functioning of another device or system.

EMC is electromagnetic compatibility and is the property of a device or system which permits it to operate without conducting or radiating harmful EMI and without its own operation being adversely affected by EMI from other devices or systems.

Conducted interference describes the potentially harmful emissions which are transferred from a device over the wires connected to it.

Radiated interference describes the potentially harmful emissions which emanate when a device inadvertently functions as a transmitting antenna.

Susceptibility of a device characterizes the degree to which it fails to possess immunity to EMI.

EMI limits are the maximum allowable levels of conducted and radiated interference, respectively, which a device is allowed to emit.

## 2.0 The Regulators

Compliance with EMI limits is imposed by regulations of our FCC (Federal Communications Commission), by the West German VDE (Verband Deutscher Electrotechniker) and by appropriate agencies in many other countries. Most European nations follow the West German approach to interference control, since the VDE regulations are completely harmonized with recommendations and publications of the CISPR (Comite International Special des Perturbations Radioelectriques), which is the Special International Committee on Radio Interference, of the IEC (International Electrotechnical Commission). Thus, the FCC and VDE regulations concerning EMI are representative of non-military EMI mandates in use throughout the world. The four-page tabulation accompanying these notes covers all the basic differences between civilian- and military-oriented emissions measurements.

### 2.1 Compliance Procedures

The VDE requires that personnel from the VDE testing station, at Offenbach, Germany, actually participate in certification procedures; whenever possible, this occurs at the VDE testing station itself.

Our FCC has a wide range of procedures for approval for various devices, ranging from actual testing at the FCC laboratories (Type Approval) to permitting the manufacturer to perform his own tests to determine compliance (Verification and Certification).

## 3.0 Basic EMI Measurements

As shown in Figure 1, basic EMI measurements involve an EMI meter (also called an "interference analyzer"), or an equivalent spectrum analyzer. (Section 5.0 discusses the relative merits of these two basic devices.) The EMI meter is a calibrated tunable RF voltmeter capable of reading the level of EMI voltage fed to its coaxial input terminal. The level of voltage registered on its front-panel meter is noted by the operator. If attenuation had to be added to keep the meter reading on-scale, through operation of the EMI meter's front-panel attenuation control, then that attenuator setting, in dB, is added

to the front-panel meter reading. The resulting total is the actual EMI voltage level and is usually expressed in terms of "dB relative to one microvolt" and written as "dBuV."

3.1 Conducted Measurements

To perform conducted measurements, such as those required by the FCC, the AC power cord of the device under test is connected to a LISN, or Line Impedance Stabilization Network, which is, in turn, connected to the AC power mains. The LISN extracts from the device's AC power cord, the interference voltage to be measured. This is carried by a coaxial cable to the input terminal of the EMI meter, as shown in Figure 1.

The LISN is a relatively simple device which performs the functions of isolating the measurement from any EMI already on the AC mains, stabilizing the impedances presented, and channeling the conducted interference to the EMI meter for measurement. A separate LISN should be connected to each side of the AC line and those RF outputs not connected to the EMI meter terminated in 50-ohm impedances.

3.2 Radiated Measurements

To measure radiated EMI, the EMI meter is fed from an antenna, instead of the LISN discussed above. As implied by Figure 1, the antenna is calibrated and characterized by an "antenna factor" k, such that multiplying the voltage, as measured at the EMI meter input, by this factor k, yields the magnitude of the radiated field in which the antenna is immersed. Since the antenna factor k is usually frequency-dependent, an antenna designed for EMI measurements is furnished with data indicating the appropriate conversion factor at each frequency in its coverage range. This factor is in terms of dB/meter and is added to the input voltage reading in dBuV, to produce field strength, in terms of dBuV/meter.

4.0 EMI Instrumentation

Although the FCC has not placed any important restrictions on characteristics of EMI measurement instrumentation in the past, adoption of Dockets 20780 and 80-284 has brought the FCC-required instrumentation characteristics into close alignment with those of VDE/CISPR. The FCC specifies an EMI meter with quasi-peak detection in conformance with ANSI (American National Standards Institute) Specifications for Electromagnetic Interference and Field Strength Instrumentation, C63.2-1980, which is completely aligned with the CISPR publications. Use of a spectrum analyzer is also permitted, provided that it possesses bandwidths not less than 9kHz, for EMI measurements below 30MHz and 100kHz, for those above 30MHz.

For measurement of pure CW (continuous wave) EMI, the choice of instrumentation makes little difference. However, the FCC has increasingly recognized, in recent years, that major differences in measured EMI levels can result when EMI which occupies a spectrum of frequencies or which is not continuous is measured with instrumentation having different bandwidth and detector characteristics. The growing commonality with CISPR/VDE instrumentation and procedures is based on this consideration and on the recognition that it is inefficient for a manufacturer to be forced to implement different EMI procedures for domestic and foreign sales.

Basic CISPR characteristics for EMI instrumentation are shown in Table 1.

| CISPR Characteristic | 10kHz – 150kHz | 150kHz – 30MHz | 25MHz – 1000MHz |
|---|---|---|---|
| Bandwidth at (-6dB) | 200Hz | 9kHz | 120kHz |
| Electrical Charge Time Constant of QP Voltmeter | 45MS | 1MS | 1MS |
| Electrical Discharge Time Constant of QP Voltmeter | 500MS | 160MS | 550MS |
| Mechanical Time Constant of Critically-Damped Meter | 160MS | 160MS | 100MS |
| Pre-detection Overload Factor (min.) | 24dB | 30dB | 43.5dB |
| Post-detection Overload Factor (min.) | 12dB | 12dB | 6dB |

Table 1-CISPR Characteristics for Instrumentation

Instruments used for CISPR measurements of frequencies between 10kHz and 1000MHz must utilize wide-dynamic-range linear amplification and carefully-defined bandwidths ahead of quasi-peak detectors, whose charge and discharge characteristics also are precisely defined. This careful attention to response of the measuring receiver obviates the need for separate attention to EMI noise characteristics such as broadband/narrowband and the repetition rate of impulsive bursts. These important considerations are already implicit in responses produced by the CISPR instrumentation. Figure 2 shows how the CISPR quasi-peak detector response falls off as a function of repetition rate, as compared to a peak-response detector, when both are preceded by the same CISPR Publication 1 pre-detection bandwidths.

## 5.0 Spectrum Analyzers Versus EMI Meters

Table II summarizes the respective strengths and weaknesses of conventional spectrum analyzers and EMI meters (also called "interference analyzers"), for EMI testing. In addition to the basic points noted in the table, some users could be affected by the consideration implicit in Figure 2: namely, the reduced readings of impulsive EMI levels by CISPR quasi-peak detection, as compared to the peak detection customary when in conventional spectrum analyzers. Expensive over-design for EMI suppression could result from use of such spectrum analyzer peak detection if the device under test produces its EMI in bursts, rather than continuously.

A new EMI spectrum analyzer, the Model ESA-1000, recently introduced by Electro-Metrics, overcomes this weakness, as well as several other problems with typical spectrum analyzers. (See notes at the bottom of Table II.)

## 6.0 Comparison of FCC/VDE and Mil-Std.-Type Emissions Testing

The accompanying four-page tabulation covers the basic requirements for EMI testing for conformance to four widely-used standards. The wide differences between the CISPR-oriented mandates (Columns #1 and #2) and the MIL-STD-oriented (Columns #3 and #4) are becoming narrowed as time passes. A pertinent example is the FCC Docket 80-284 relaxation of 13dB for line-conducted noise determined to be broadband by comparison of average and peak/quasi-peak responses.

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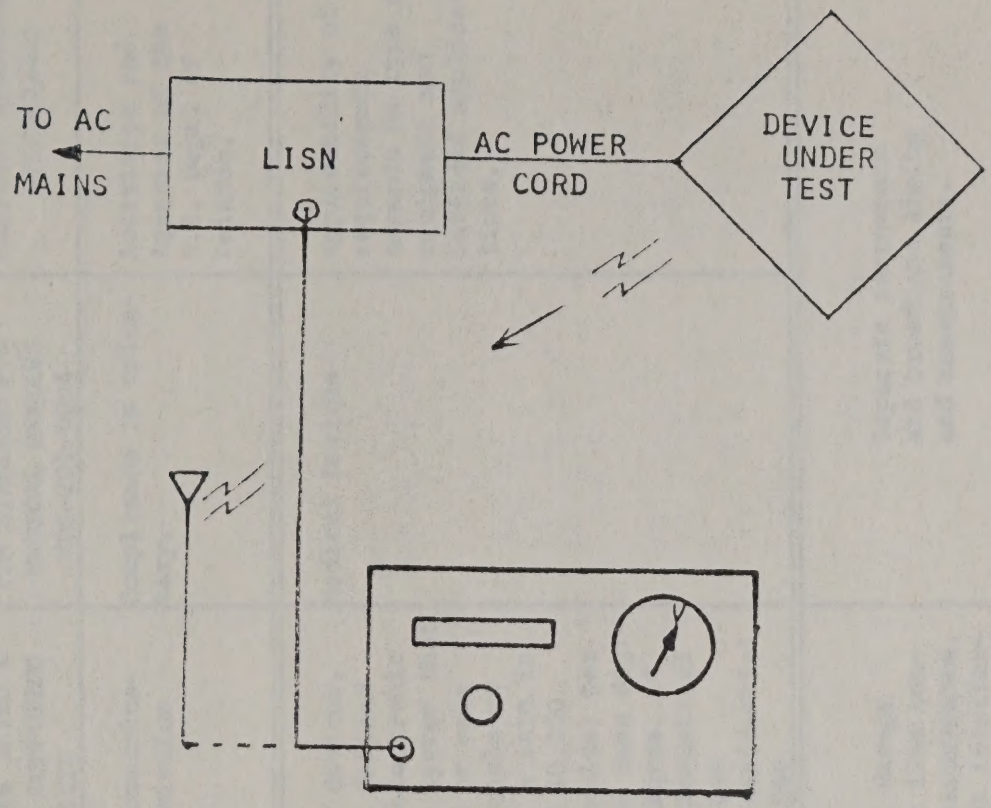
Note: The accompanying information is intended as an introduction to the subjects discussed. Although data is believed correct as of this writing, the reader is cautioned to obtain latest issues of applicable documents, which might incorporate changes.

TABLE II

SPECTRUM ANALYZERS VS EMI METERS FOR EMI TESTING

| CAPABILITY | TYPICAL SPECTRUM ANALYZER | TYPICAL INTERFERENCE ANALYZER |
|---|---|---|
| 1- WIDE DISPERSION VIEWING | YES, MANY OCTAVES | SINGLE OCTAVE W/AUX. SCOPE |
| 2- NON-EMI APPLICATIONS | YES, MANY | LIMITED |
| 3- RF SENSITIVITY FOR EMI TESTING | SOME PROBLEMS | YES, BY DESIGN |
| 4- EMI BW'S AND TIME CONSTANTS | LIMITED EXTENT* | YES, BY DESIGN |
| 5- FRONT-END PRE-SELECTION | PARTIAL, BY ACCESSORY | YES, BY DESIGN |
| 6- ACCURACY ON WIDE-BAND NOISE | FREQUENT PROBLEMS | GOOD, BY DESIGN |
| 7- BUILT-IN BROADBAND CALIBRATOR | NO | YES |
| 8- COMPATIBILITY WITH EMI PICKUPS | SOME PROBLEMS** | GOOD, BY DESIGN |
| 9- ACCURATE RECORDING OF PEAK LEVELS | DIFFICULT TO PHOTOGRAPH*** | YES, WITH PEAK-HOLD X-Y PLOTS |
| 10- EASE OF USE FOR EMI TESTING | PRECAUTIONS NEEDED | YES, BY DEDICATED DESIGN |

*Model ESA-1000 has required FCC/CISPR bandwidths and detector time constants, 100kHz-1000MHz.
**Model ESA-1000 incorporates digital offset for antenna factor vs. frequency.
***Model ESA-1000 offers optional DM-1000 memory unit to facilitate.




FIELD STRENGTH,

E = kV, WHERE

k = ANTENNA FACTOR

V = MEASURED VOLTAGE

FIGURE 1-BASIC EMI MEASUREMENT

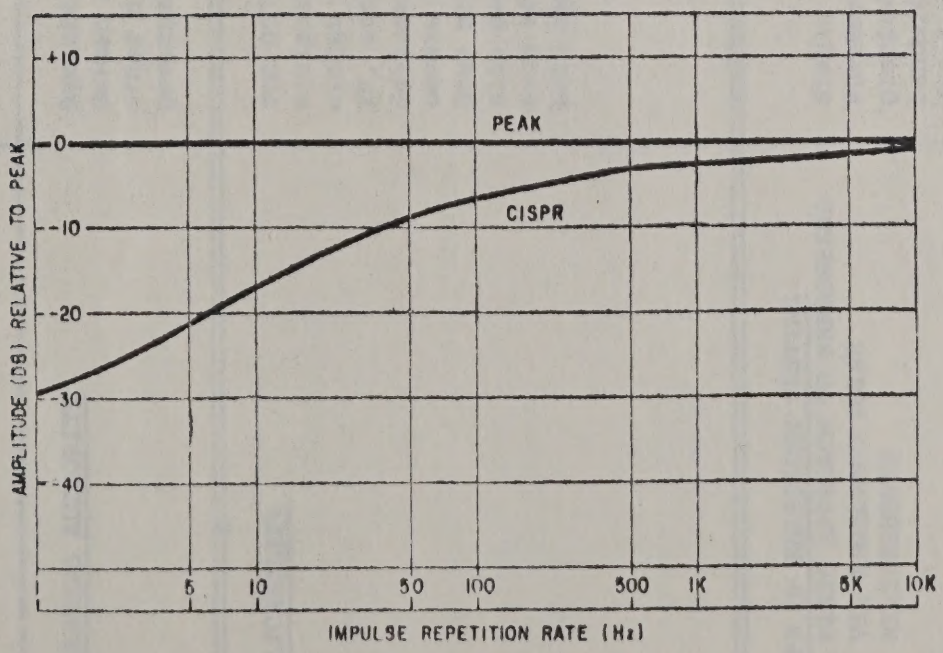
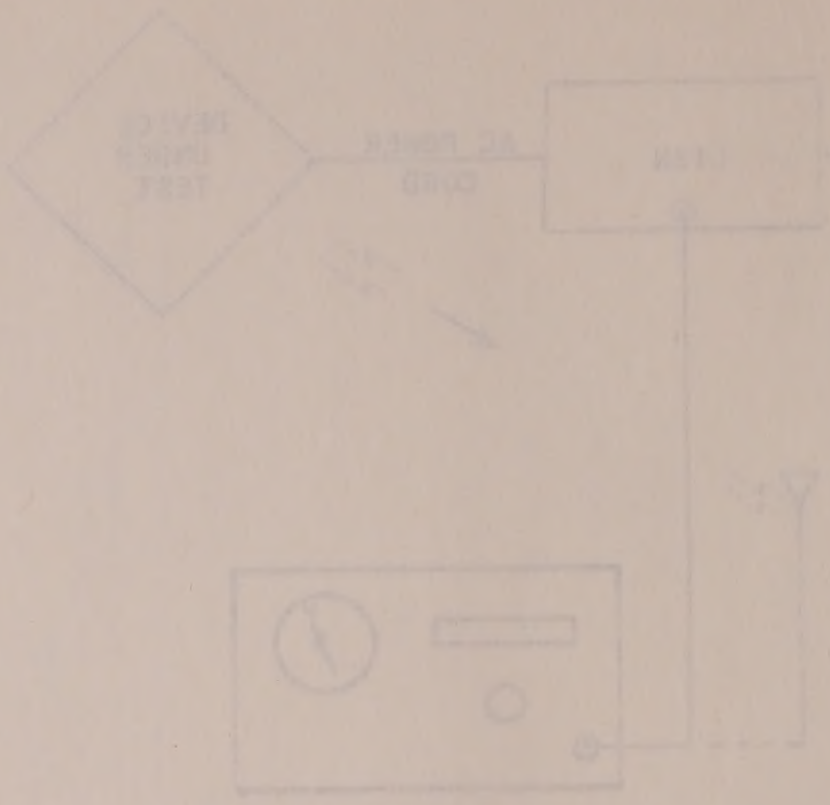
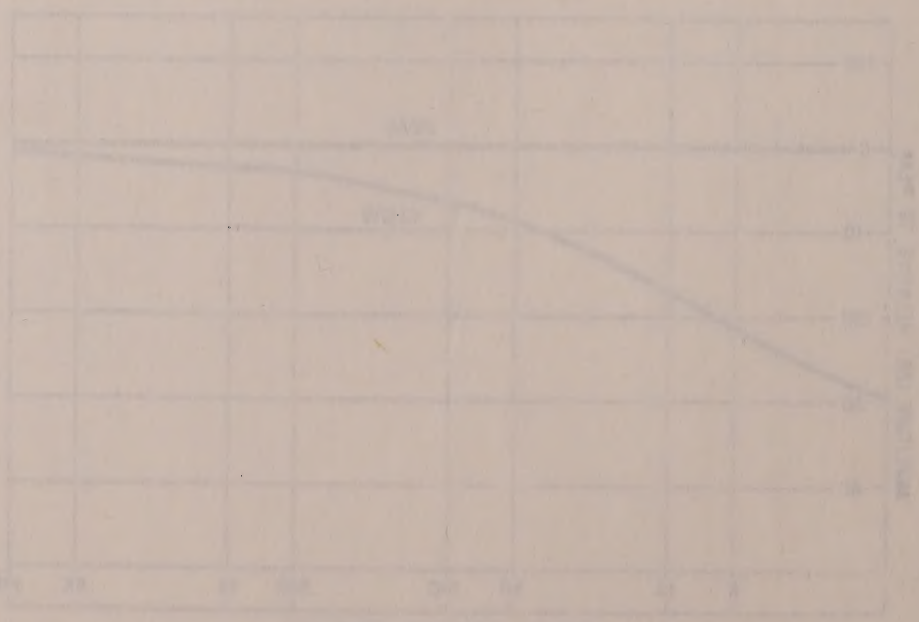



FIGURE 2-CISPR Q-P VS PEAK (0.15-30MHZ)





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# BASIC REQUIREMENTS FOR EMI EMISSIONS TESTING per

| | #1 CISPR PUBLICATIONS & VDE SPECIFICATIONS | #2 FCC DOCKETS 20780 & 80-284 FOR COMPUTING DEVICES | #3 FDA STANDARD FOR MEDICAL DEVICES MDS-201-0004 | #4 MILITARY STANDARDS 461/462/463 |
|---|---|---|---|---|
| 1.0 REGULATING AUTHORITY | Agencies of the West German and numerous other national governments. | Federal Communications Commission (U.S.). | Compliance is voluntary. | Activities and Agencies of the U.S. Dept. of Defense. |
| 2.0 APPLICABILITY | VDE 0871 covers equipment which generates or processes RF, such as computing devices. VDE 0875 covers equipment that does not intentionally generate RF, such as most household appliances. | Computing devices, which are defined as, "any electronic device or system that generates or uses timing signals or pulses at a rate in excess of 10,000 pulses (cycles) per second and uses digital techniques..." Class A: Industrial Use Class B: Residential Use | Medical Devices | Applicability of requirements depends on type of equipment and intended applications. |
| 3.0 SCOPE OF EMISSIONS TESTING<br>3.1 BASIC APPROACH TO NARROWBAND VS. BROADBAND NOISE MEASUREMENTS | Single sets of measurements, using precisely defined bandwidths and quasi-peak detectors. | ← Same, except that, for line conducted measurements, quasi-peak interference readings are reduced by 13dB for limit comparison if average detector reads significantly less than quasi-peak detector, indicating BB noise. | Separate narrowband and broadband limits and measurements. | |

| | CISPR/VDE | FCC COMPUTING DEVICES | MDS-201-0004 | MIL-STD 461/462/463 |
|---|---|---|---|---|
| 3.1.1 CONDUCTED UNITS | dBuv | uv | Narrowband: dBuA<br>Broadband: dBuA/MHz | |
| 3.1.2 RADIATED UNITS | uv/m | uv/m | Narrowband: dBuv/m<br>Broadband: dBuv/m/MHz | Magnetic Field: dBpT |
| 3.2 CONDUCTED MEASUREMENTS FREQUENCY RANGE | 150kHz-30MHz<br>(10-150kHz pending) | 450kHz-30MHz | NB: 500Hz-30MHz<br>BB: 1kHz-30MHz | NB: 30Hz-50MHz<br>BB: 15kHz-50MHz<br>Antenna Conducted:<br>NB & BB: 10kHz-12.4GHz |
| 3.3 RADIATED ELECTRIC FIELD MEASUREMENT RANGE | 150kHz-1000MHz<br>(10-150kHz pending) | 30-1000MHz | 10kHz-1000MHz<br>(NB and BB) | NB: 14kHz-10GHz<br>BB: 14kHz-1000MHz<br>Antenna Harmonics & Spurs: 10kHz-40GHz |
| 3.4 RADIATED MAGNETIC FIELD-MEASUREMENT RANGE | ---- | ---- | ---- | NB: 30Hz-50kHz |
| 3.5 BASIC TEST SITE FOR RADIATED MEASUREMENTS | Open-Field | Open-Field.<br>Anechoic chamber OK, provided test methods adjusted to accommodate. | Shielded Enclosure | |
| 3.6 ANTENNA DISTANCE FROM TEST SAMPLE | 3/10/30/100m | Class A: 3-30m, extrapolated to 30m<br>Class B: 3-10m, extrapolated to 3m<br>Extrapolations by 1/d | 1 meter | |

| | CISPR/VDE | FCC COMPUTING DEVICES | MDS-201-0004 | MIL-STD 461/462/463 |
|---|---|---|---|---|
| 3.7 TEST SAMPLE HEIGHT FOR RADIATED MEASUREMENTS | 0.6-0.8m | Table-mounted: ≈ 1m<br>Floor-mounted: ≈ 0.5m | Positioned on ground plane | |
| 3.8 HEIGHT OF TEST ANTENNA, h | For max. pickup, but not to exceed 3.6m | For d ≤ 10m, vary h over 1-4m<br>For d ≥ 10m, vary h over 2-6m | Centered on test sample | For max. pickup at 1 meter spacing |
| 4.0 INSTRUMENTATION AND PICKUP DEVICES<br>4.1 BASIC INSTRUMENTATION SPECIFIED OR IMPLIED | EMI meter per CISPR Publications 1-4 and VDE Spec. 0876 | Primary: EMI meter per ANSI C63.2-1980<br>Alternative: Spectrum Analyzer | EMC receiver with peak measurement capability | EMI meter or spectrum analyzer with peak measurement capability |
| 4.2 PRINCIPAL INSTRUMENTATION CHARACTERISTICS | Quasi-peak detection with detector charge/discharge, pre-detection bandwidth, and other characteristics specified versus RF range. | | Not specified, per se, but implied sensitivities and bandwidths to measure NB and BB noise to applicable limits using scanning techniques and peak detection. | |
| 4.3 COUPLING DEVICES FOR CONDUCTED MEASUREMENTS | 50-ohm, 50uh LISN to read interference voltage. Absorbing clamp to measure interference power conducted from small appliances via AC power line. | 5uh LISN may be used with correction factor, as required. | Clamp-on current probes with calibrated transfer impedances, to read interference currents. | Some limited use of LISN's (Notice 3-461A) |

| | CISPR/VDE | FCC COMPUTING DEVICES | MDS-201-0004 | MIL-STD 461/462/463 |
|---|---|---|---|---|
| 4.4 ANTENNAS FOR RADIATED MEASUREMENTS | 10kHz-30MHz: Magnetic Loop<br>25-1000MHz: Tuned dipoles or correlateable linearly-polarized equivalents. Below 80MHz, dipole is fixed-tuned to 80MHz. | 30-1000MHz: | Not specified, except collective coverage is 10kHz-1000MHz and both vertical and horizontal polarizations must be measured above 200MHz. | Electric Field Measurements:<br>14kHz-30MHz: 41" Vertical Rod<br>30-200MHz: Biconical<br>200-1000MHz: Log Conical (Circularly polarized)<br>1-12.4GHz: Double-Ridged Waveguide Horn |